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Cereal Rust of Small Grains

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BOTANY AND PLANT PATHOLOGY SECTIONS

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CEREAL RUST OF SMALL GRAINS

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The cereal crops of Iowa and the upper Mississippi valley are annually attacked by five different rusts which are frequently considered identical by many grain growers. Altho superficially they resemble one another closely, their differences are marked, not only to the eye but also as to their economic importance. One of these rusts occurs chiefly on the stem of oats, wheat, rye and barley and is known as black stem rust, while the other four are leaf rusts, occasionally attacking the stems.

The ravages of grain rusts are well known and watched with much anxiety by the farmer when his grain crop is maturing. In 1916 stem rust reduced the grain crop of the middle west 200,000,000 bushels while in 1917 and 1918 it did comparatively little damage, its destructiveness being periodic, depending on weather conditions. The leaf rusts, on the other hand, tho not as destructive as stem rust, are of importance because they destroy the leaves, the food machinery of the plant.

Fig. 1. The common or purple leaf barberry, which grows from 6 to 12 feet tall, has a light green colored bark, and green or purple leaves with saw-toothed margins. The flowers and fruit are borne in currant-like clusters, and the spines are three-pointed.

Rusts are caused by microscopic plants closely akin to such organisms as bread mold, and green mold of decaying fruit. The differences between these rusts are given so that they may be distinguished from one another. Some of the grain rusts are peculiar in that they must have two different plants to complete their life cycles. This is the case with stem rust. In the spring it spreads from grain to the common barberry and back to grain again the same season. If we can absolutely eliminate the barberry from the middle west, serious outbreaks of stem rust will not occur. Obviously therefore, it becomes of great

importance to know the relation, distribution, prevalence, history and means of killing this shrub.

BLACK STEM RUST

Black stem rust (*Puccinia graminis*) lives part of its life on grain crops and part on the common barberry from which it again spreads to the grain. This has been known for more than 50 years, but it is only within the last decade that we have come to appreciate fully the important role this shrub plays in spreading the disease.

The common barberry (fig. 1) was introduced from Europe and is used for ornamental purposes in parks, on lawns, and along drives. It has no commercial value other than an ornament and there are numerous other shrubs that are fully as desirable, especially a closely related species, the Japanese barberry, which is immune to rust, (fig. 2.)

HOW STEM RUST LIVES

Black stem rust appears in the fall and spring on stubble and straw as long black blister-like spots filled with winter spores or "seeds" of the fungus (fig. 3 B and fig. 4 B.) These start to grow or germinate in the spring and produce another crop of spores (fig. 3C) that are blown by the wind to the leaves of the barberry. Under favorable conditions these secondary spores germinate and penetrate the leaves of the barberry (fig. 3 D and F and fig. 5). These yellow spots on the barberry leaves are filled with another crop of spores (fig. 3 C) which are very light and easily blown about, some finding their way to grain fields where once on the leaves and stems of the grain they send their

Fig. 2. The Japanese barberry, a low shrub with reddish brown bark. Its flowers and red berries are usually borne singly or in twos or threes. The leaves are small and green tinged with red. The spines are usually single pointed on the older wood. On the current year's growth they are sometimes three pointed as on the common barberry. It does not spread stem rust and is a good substitute for the common barberry.

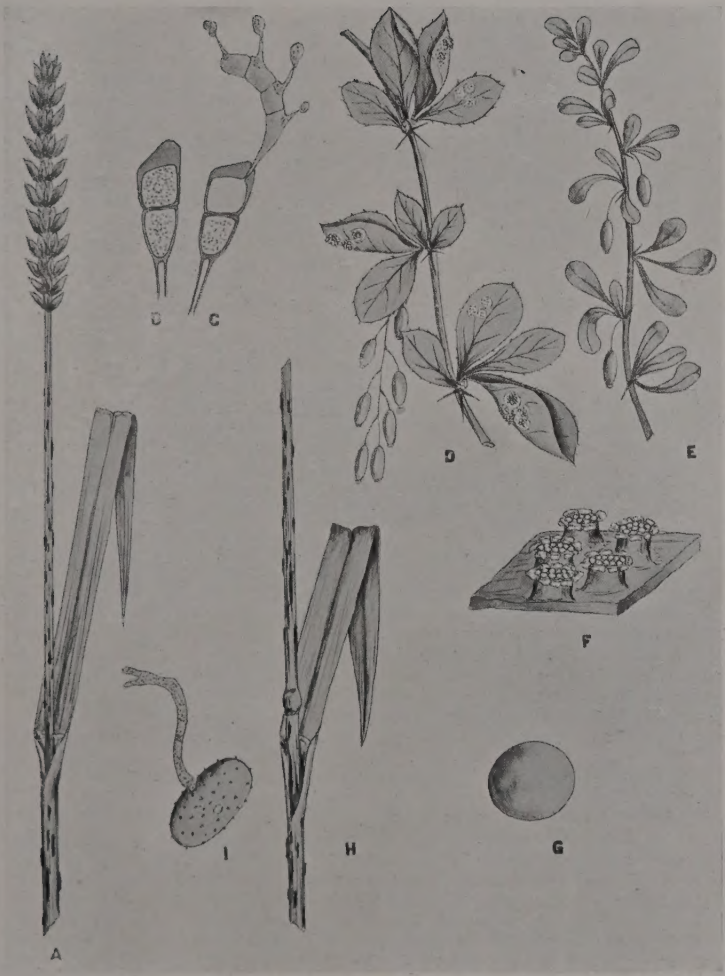

Fig. 3. Stem rust on grain and common barberry.

A. Red rust stage on wheat.
B. Black or winter spores.
C. Winter spores starting to grow.
D. The rust on common barberry leaves.
E. Japanese barberry which is immune to stem rust. Notice difference in edges of leaves, spines, and way the berries are borne.
F. An enlarged view of the rust on barberry. The rust spores are borne in little cups and are sometimes called cluster cups.
G. A single barberry rust spore.
H. Red rust stage on wheat stem.
I. A red rust spore starting to grow.

threads into the tissues and in about a week grow into brick red blisters. In each of these blisters are thousands of other spores, the red rust spores, (fig. 4 A and fig. 3 I) each one of which may blow to neighboring grain plants and in turn germinate and cause additional rust. It is the red rust spores that fly so profusely when grain is being cut during severe outbreaks of the disease. It is plain to be seen that when this rust parasite has once gotten into a field it may spread rapidly.

The rust has usually obtained a good foothold in the fields by the time the grain comes into blossom. At this time the foliage is dense, dew and rain evaporate slowly leaving very desirable conditions for germination and growth of rust. It is usually between the time of heading and ripening of the grain that the rust becomes abundant and does serious damage. When grain lodges it always rusts more severely.

THE BARBERRY IN RELATION TO BLACK STEM RUST

The winter spores of rust found on stubble and straw, are incapable of growing on other grain when they germinate, but can only go to the barberry. The relation of this bush to the rust, therefore, is a vital one. There are several species of barberry susceptible to rust which were found growing in Iowa; namely, the European or common barberry (*Berberis vulgaris*), purple leaf barberry (*B. atropurpurea*) and Amur river barberry (*B. amurensis*). The Amur river barberry was found only in one locality and has been eradicated. The common barberry is a tall shrub from six to twelve feet high, bearing large leaves (1 to 2½ inches long) with spiny margins and three pointed thorns on the stems. The bark is a characteristic gray. The flowers and fruit are borne in clusters. The purple leaf barberry altho listed and sold by the nurserymen as a separate species is in reality only a variety of the common barberry, having purple instead of green leaves. Otherwise it does not differ from the common barberry. The shrub is shown in fig. 8. The Japanese barberry is a low, dense bush growing from 1 to 4 feet tall, bearing small, smooth margined leaves, ½ to 1½ inches long, and single pointed spines borne below the leaf clusters; it has reddish brown bark and usually the flowers and fruit are borne singly as shown in fig. 6. This variety is immune to the rust. (fig.2).

NUMBER OF BARBERRIES IN IOWA

During the past two years a great many barberry bushes have been found in the state growing as hedges in the country and town or as clump plantings on public and private grounds in the cities. Previous to 1917 all of the nurseries in the state carried extensive plantings for distribution. In some cases these plantings covered five acres. In addition to being domesticated this shrub is at present tending to run wild in some localities, 20 such places having been found. Data at hand shows that in 1917 before the barberry eradication movement was begun, there were in Iowa at least a million bushes. Their distribution was general over the state, and they were found in every county. Altho the largest number were found in the larger cities, as Dubuque, Davenport, Des Moines, and Sioux City, yet the small towns and farmsteads were frequently found to have barberry plantings. As the survey continues the number of bushes located in the country is continually increasing and it is quite probable that the total number found there will finally equal the number found in the towns.

Thru the appeal made by the United States Department of Agriculture and the state during 1918, over 400,000 of these bushes were voluntarily destroyed by the owners in order to protect the grain crop from stem rust.

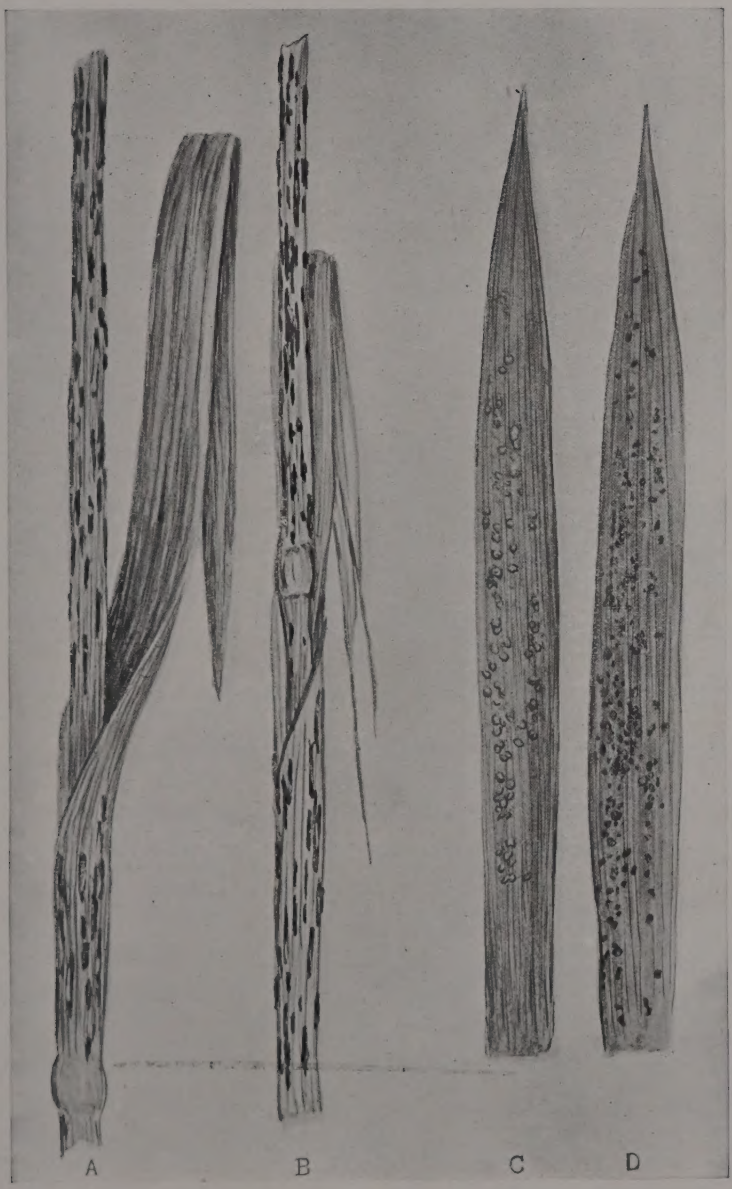

Fig. 4
A. Red or summer stage of black stem rust of wheat
B. Black or winter stage of black stem rust of wheat
C. Crown or leaf rust of oats—summer stage
D. Leaf rust of wheat—summer stage

Fig. 5. Rust on leaves of a young barberry bush. The spores are produced in yellow spots on lower surface of leaves. Often the leaf is bulged upward at the point where rust occurs. Almost every bush has some rust on it between May first and the last of July.

BARBERRY BECOMING WILD

It has already been mentioned that the common barberry is not native in America, and that it was introduced into Iowa. Like many introduced plants the barberry has begun to establish itself in several localities in Iowa. Some striking instances of this have been found, notably at McGregor, LaClaire, Cascade, Garner, and Montpelier. In no place, however, has the plant escaped far from the original planting. In each instance the chief agent of distribution seems to be birds. The longest distance from the original planting is about one mile. In every instance the shrub escaped into native timber or planted groves. In a few cases bushes were found along fences. The bushes seem to be unable to establish themselves in fields or pastures where trees do not occur (fig. 7). There can be little doubt that as time went on this shrub would become established in a large number of places where underbrush and timber land occur in the state. Its menace to the grain crop would thereby be increased many fold.

SPREAD OF STEM RUST FROM COMMON BARBERRY TO GRAIN

It has been noticed in Iowa that wherever the barberry bush was found growing it was at sometime between April and August infected with rust. In some cases the amount was slight while in other cases hardly a leaf escaped infection. In 1918 the rust on the barberry was found in 99 different places scattered over the state. The greatest amount of infection was found on the older plantings about the smaller towns and in the surrounding country.

The first appearance of the rust during the last four years has been found to be as follows:

Spore Stages	Host	1916	1917	1918	1919
Germinating black rust spores	Stubble and grasses		April 21	May 3	April 3
Barberry rust	Barberry	May 7	May 5	May 8	April 29
Red rust	Wheat and oats	May 21	June 15	May 25	June 17

It is shown here that the black rust spores germinate freely before the first barberry rust appears and also that the red rust stage

on the grains and grasses appears after the barberry rust. In each case the rust found on the common barberry showed every sign of being the initial stage, sufficient time intervening to permit the stage on the barberry to function and start the rust on grain.

OUTBREAKS OF RUST TRACED TO THE BARBERRY

During the summer of 1918 and 1919 additional evidence has been collected which shows clearly that the common barberry may start local outbreaks on grasses and grains in their immediate vicinity. Near infected barberry bushes, the following grasses were found infected with stem rust; squirrel tail, red top and quack grass. These wild grasses, on account of their universal presence and long growing period, are an important factor in the starting of local outbreaks of stem rust.

Sixteen local outbreaks of stem rust were traced directly to the barberry in 1918. It attacked not only the various wild grasses but spread to oats, wheat and barley. In the case of the oats and wheat serious damage resulted. The rust spreads in concentric zones and most rapidly in the direction of the prevailing wind. Evidence indicates that the wind may carry the rust long distances. Hedges in the country and bushes in the outskirts of towns were found to be the most serious offenders; however, there is every reason to believe that bushes in the larger cities also may aid the spread of stem rust. Some bushes may serve to aid the spread of stem rust one year and not the next; other bushes may function only occasionally. Such functioning depends upon local conditions, such as the presence of grasses, direction of prevailing wind, and favorable weather conditions for infection when barberry rust is being produced. Fig. 8 shows a map of a representative case of infection of grain from neighboring barberry bushes.

CONTROL OF STEM RUST

The most practical way of reducing the losses from stem rust known up to the present time is first, to grow varieties that mature before the rust has time to become markedly prevalent and destructive; second, to develop resistant varieties of grain; and, third, to destroy its alternate host, the common barberry.

In the case of wheat, the winter wheats usually mature earlier than the

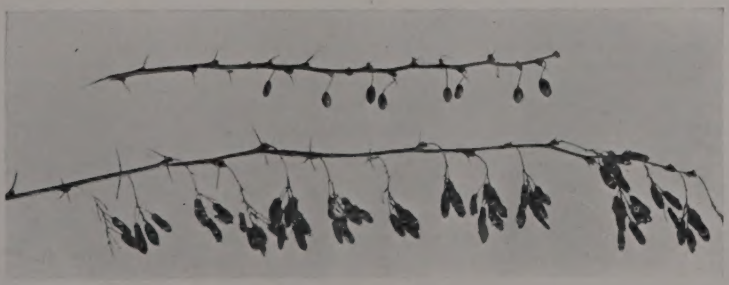

Fig. 6. Japanese and common barberry, showing marked difference in size and way in which flowers and berries are borne. The Japanese barberry usually has single pointed spines, while the common has three pointed spines.

Fig. 7. The common barberry is becoming wild in some places in the state, and while it cannot maintain itself in open fields or pastures, it is able to gain a footing in wood lots and timberland where underbrush flourishes.

spring sorts and escape serious infection from stem rust. The late spring varieties suffer more from stem rust than the early sorts. None of the commercial wheat varieties are markedly resistant to stem rust.

Like winter wheat, the early oats escape without much damage and some of the late varieties are quite resistant; this is especially true of some of the Green and White Russian. Of the cereals late barley suffers more from stem rust than any of the others, and none of the varieties commonly grown in the state show any appreciable degree of resistance.

The eradication of the common barberry offers the greatest immediate relief, judging from the experiences of England and Denmark. The eradication movement began in the United States in 1916 when North Dakota and the Province of Manitoba, Canada, passed barberry eradication measures. In 1919 most of the states in the spring wheat growing section of the middle west passed laws requiring the extermination of the common barberry, namely: South Dakota, Wisconsin, Minnesota, Michigan, Colorado, Montana, Nebraska, and Iowa.

In this state the eradication of the barberry began in the spring of 1918 as a war emergency measure instituted by the French Government in cooperation with state agencies. The thirty-eighth general assembly of Iowa enacted an amendment to the Iowa Crop Pest Law making it illegal for anyone to have or grow the common barberry. The section of this law having to do with the barberry is as follows:

Section 2575—A 51 Supplement to the Code 1913

Article I. QUARANTINE, TREATMENT, COLLECTION OF COST. The State Entomologist shall have authority, when requested by the owner or agent, or when he has reasonable grounds to believe any dangerously injurious insect or plant disease exists, to enter upon any grounds, public or private, for the purpose of inspection, and, if he finds any nursery, orchard, garden or other place infested by any dangerously injurious insect or plant disease, he may, by himself, or his

assistants, enter upon such premises and establish quarantine regulations. If in his judgment the dangerously injurious insect or plant disease may be eradicated by treatment, he may, in writing, order such treatment, and prescribe its kind and character.

In case any trees, shrubs or plants are found so infested that it would be impracticable to treat them, he may order them destroyed or burned.

Article II. Wherever in the judgment of the State Entomologist it is found that any other dangerous crop pests or carriers exist, he shall take such additional measures as seem fit to protect the crop or industry concerned.

After notification by Entomologist it shall be unlawful for any person, firm or corporation to receive, ship, or accept for shipment, transport, sell, or offer for sale, give away, deliver, plant, or permit to exist on his or its premises any plant of the harmful barberry or any other plant that acts as an alternate host or carrier of a dangerous insect pest or plant disease.

The term, "Harmful Barberry," shall be interpreted to consist of any species of Berberis or Mahonia susceptible to infection by *Puccinia graminis*, commonly called Black Stem Rust of grain, but not including Japanese barberry (*B. Thunbergii*).

Article III. It shall be the duty of the State Entomologist and his assistants, to enforce the provisions of this section and he is hereby empowered to eradicate any such insect pest, plant disease or carrier of insect or plant disease.

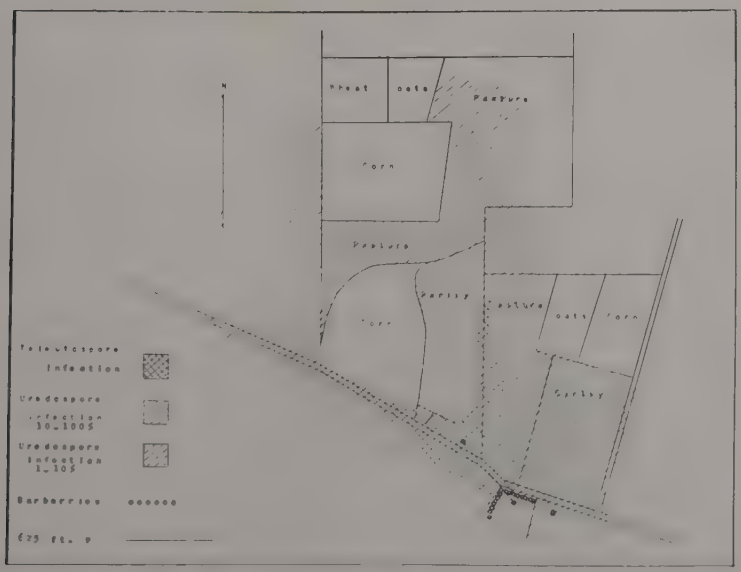

Fig. 8. The small circles represent the hedge of common barberry growing near the road. Records taken in 1918 show that the rust spread from the bushes to the grain across the road for nearly a mile outside of this region, indicated by the shading. The rust spread farthest in the direction of the prevailing wind. Had the weather been more favorable than it was in 1918 this rusted area would have been much larger.

If the owner shall refuse or neglect to eradicate such pest or carrier, within ten days after receiving a written notice, the State Entomologist shall eradicate or cause to be eradicated and ascertain the cost thereof. He shall certify the amount of such cost to the owner or person in charge of the premises, and if the same is not paid to him within sixty days thereafter he shall certify the amount to the county auditor, who shall spread the same upon the tax books, to be collected as other taxes are, and turned over to the Entomologist to become a part of the fund for carrying this act into effect.

DIG UP BY THE ROOTS

It is not sufficient to cut barberry bushes off at the surface of the ground. They must be dug up by the roots and burned, otherwise they throw up new sprouts that rust worse than the old plants. Many of such cases have come to our attention and it is such cases that will materially prolong the job of killing all the barberries in the state. No matter how large a bush may be, its roots are never deep in the ground. It roots near the surface and has a tendency to throw up new shoots from the larger roots. As a result every root the size of a pencil must be dug out and allowed to dry in the sun. Large bushes standing in hedges or growing wild are best grubbed out by using a team with a log chain hitched to the bush down at the crown. If the large roots on one side are cut before the team pulls, the bush comes out without much difficulty. In fig. 9, an 80-rod common barberry hedge is being grubbed out by using a team.

LEAF RUSTS

In addition to stem rust we find grains are attacked by leaf rusts. These rusts do not, however, cause as much damage as stem rust, but

Fig. 9. The common barberry growing in hedges is best removed with a log chain and team. The log chain is fastened to the bush just above the crown and the lateral roots on the side opposite the team cut with an ax or sharp spade. This method enables the team to pull out the bush as well as most of the roots.

their injury on the leaves of the grain is by no means trifling. Altho they may attack the leaf sheaths, stems and glumes, they are usually confined to the leaves. They differ in this respect markedly from black stem rust. The four leaf rusts are as follows:

Crown rust on oats
Leaf rust on wheat
Leaf rust on rye
Leaf rust on barley

CROWN RUST OF OATS

This rust (*Puccinia coronata*), so called because of the crown-like prongs found on the top of the winter spores, is a leaf rust, rarely occurring on the stems. It occurs only on oats, never on wheat, rye or barley. Sometimes it is found on certain of the wild grasses as sweet vernal grass, oat grass, and meadow fox tail.

Crown rust of oats is generally distributed over the state and it usually makes its first appearance between the first and middle of June. The earlier it appears the more destructive it becomes, depending to a certain extent upon the weather conditions after the grain has headed. During severe attacks of this rust, it is not unusual to see the harvesters orange red with rust spores and in such cases it is obvious that the crown rust is doing serious damage to the crop.

It is easily distinguished from stem rust by the brilliant orange colored masses of spores on the oat leaves and leaf sheaths (Fig. 9D). These are usually round to oval in shape and about one-thirty-second of an inch in diameter as shown in fig. 10E. The winter spores are crowned and in this respect differ from the stem rust spores as shown in fig. 10F. It also differs from stem rust in that it may live on the buckthorn (fig. 10A) instead of the common barberry; otherwise, its life history is quite like that of stem rust. The stage on the buckthorn is shown in fig. 9, A and B.

RELATION TO BUCKTHORN*

From the buckthorn crown rust spreads back to oats in exactly the same way as described in connection with the barberry and stem rust. Instances are common where this occurs each season in Iowa and the upper Mississippi Valley.

In addition to using the buckthorn to renew its annual appearance in the spring, crown rust may also overwinter in the red rust stage on volunteer grain during mild winters in southern Iowa.

There are three kinds of buckthorn in Iowa. Two of them have been introduced from Europe and are sold by nurserymen for ornamental and hedge purposes. These are *Rhamnus cathartica* and *R. frangula* both of which grow to be about twice as tall as the common barberry but they have no spines. The latter species is very resistant to the alternate stage of crown rust of oats. The general appearance of the most commonly planted buckthorn in this state is shown in fig. 11. The third buckthorn, *R. lanceolata*, grows wild in the southern half of Iowa along the small streams and the deep ravines. It reaches its most northern distribution in the Missouri and Mississippi river valleys.

*It should be emphasized that Buckthorn and Buckbrush are two markedly different plants.

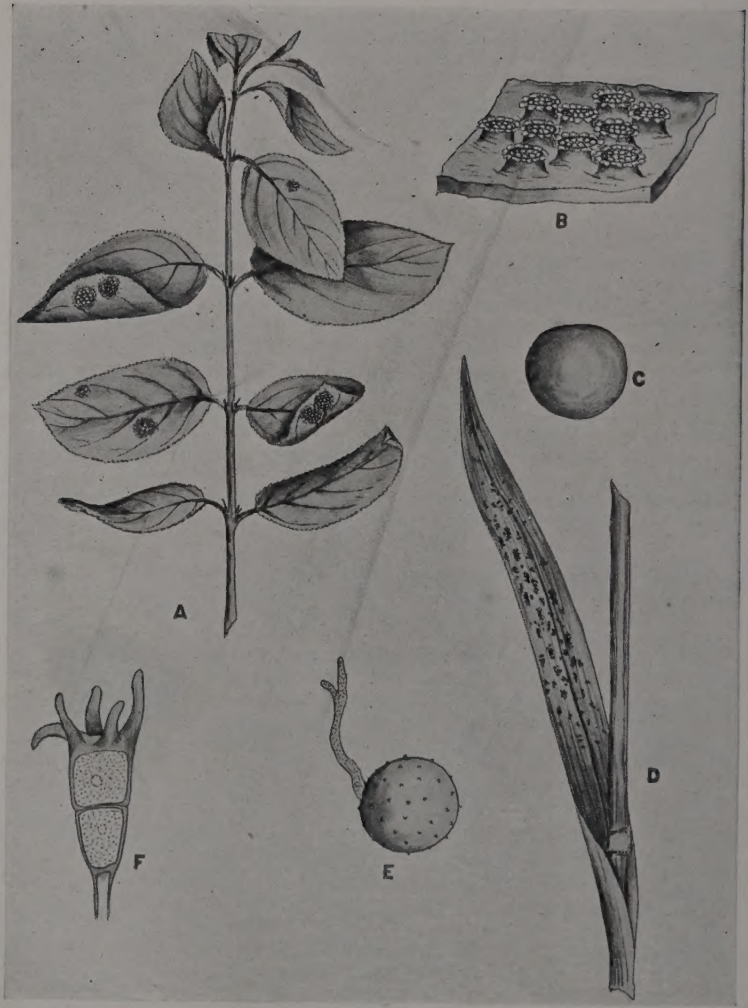

Fig. 10. Different stages of crown rust on oats and buckthorn

A. A twig of buckthorn, showing rust on leaves.
B. A small portion of the rust spot of the buckthorn enlarged. Notice the small cups full of spores.
C. One of the spores aken from the small sups produced on the buckthorn.
D. The red rust stage on oat leaves.
E. A red rust spore starting to grow.
F. The winter spores are crowned at the large end, thus the name crown rust.

Fig. 11. A four-year old buckthorn bush

CONTROL

Crown rust is favored by thick seeding, rank growth, lodging, poor drainage, and the proximity of buckthorns. These conditions should be avoided. It has been found that there is a difference in the susceptibility of varieties of oats to crown rust. This is especially true of those belonging to the red oat group as for example the variety known as Burt, Green Russian, a yellow oat, has also been found to be quite resistant. Both of these varieties are already grown to some extent in this state. In general, late varieties suffer more with crown rust than the early sorts. Except in years when this rust is very severe, susceptible early sorts as Sixty-day, Iowa 105, Early ripe and Iowa 103 escape crown rust by maturing before the rust has time to become abundant.

LEAF RUST OF WHEAT

Leaf rust of wheat (*Puccinia triticina*), shown in fig. 4 D, is present to some extent every year and tho it sometimes causes considerable loss, it is not comparable to that from black stem rust. The rust appears early in the season (May 10 in 1919) on the leaves of winter wheat, often when the plants are less than a foot high. The small, round or oval reddish blisters or pustules of spores are at first scarce but if the weather is favorable the rust may spread so that by heading time the leaves, leaf sheaths, and stems are badly scarred with pustules containing reddish spores. Under such favorable conditions it is not uncommon to find the glumes and awns of the heads infected. When the rust is so severe as to kill the leaves, considerable indirect damage is done, as in the case of crown rust of oats, with resulting light grain.

As the leaves bearing the red summer spores die, the black winter spores are developed in their stead, but usually do not break thru the epidermis as do the spores of stem rust. This rust is unlike stem rust in having no known alternate host corresponding to the barberry. The winter spores do not function and the rust is thot to winter over in the summer spore stage on winter grain or perennial grasses.

LEAF RUST OF RYE

Leaf rust of rye (*Puccinia dispersa*) is similar to the leaf rust of wheat and in fact is considered a variety of the latter, especially adapted to rye. It appears on rye early in May and is known to live over-winter on winter rye. Where rye matures early, little damage

occurs, but if it is late and the land is low and wet, the loss is heavy. Like leaf rust of wheat, it also has no alternate host corresponding to the barberry. It is thot to live over the winter in the summer spore stage.

The leaf rust of rye is the first rust to appear in the spring. It appears the last of April or the first part of May, depending upon the season. The rust is confined to the leaves only, appearing as reddish pustules similar to those of leaf rust of wheat, (fig. 4 D).

DWARF LEAF RUST OF BARLEY

This rust (*Puccinia simplex*) is also similar to the leaf rust of wheat, being exclusively a leaf rust with special preference for barley. The stage corresponding to the barberry in the life of black stem rust is unknown. The leaf rust of barley has but recently been introduced into this country from Europe. It comes late in the season and appears to have little injurious effect on the crop.